Electron-Capture Delayed Fission Study of ^{246}Es

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We continued our study of electron-capture delayed fission (ECDF) in the neutron-deficient Es isotopes with ^{246}Es. The ^{246}Es was produced at the LBNL 88-Inch Cyclotron via the ^{249}Cf(p, 4n)^{246}Es reaction. According to SPIT[1], a neutron evaporation code, the production cross section would be 350 μb for 37 MeV protons. Based on this cross section, we expected to make 1 X 10^8 ^{246}Es per day.

The ^{249}Cf targets were prepared by first performing an extraction with bis(2-ethylhexyl)orthophosphoric acid (HDEHP) to remove Bk, and then electroplating the Cf onto Be foils. 19 targets between 6 μg/cm^2 and 20 μg/cm^2 were prepared and stacked in our light ion multiple (LIM) target system.[2] Reaction products were transported with a He/KCl aerosol jet via a capillary to our MG rotating wheel detection system. The aerosols were collected consecutively on 80 thin polypropylene foils located on the periphery of the wheel which was moved every two minutes between six pairs of PIPS detectors to look for ^{246}Es alpha particles as well as fissions. Some samples were removed from the foils with a buffered solution of acetic acid and sodium acetate maintained at pH 5 and extracted with 0.5 M thenoyltrifluoroacetone (TTA) in toluene. TTA complexes 3+ and higher oxidation states from aqueous solutions between pH 4 and 5.[3] Es and Cf are complexed by the TTA, removing them from the KCl and any interfering activities. The TTA was dried on glass cover slips and placed in front of a solid state particle detector which was sandwiched between two x-ray detectors. This configuration allowed us to look for K x-rays, which follow EC decay, in coincidence with fission fragments. Once the initial EC activity is determined, the probability of delayed fission (P_{DF}) is calculated by comparing the number of delayed fissions to the total number of EC decays.

During the experiment we saw 25 times fewer ^{246}Es than predicted. The spectra showed multiple components in the Es region indicating that several isotopes were being produced concurrently. The last samples collected were counted for several days after the end of the experiment to look for ^{246}Cf ($t_{1/2}$ = 1.5 d.) Based on the amount of ^{246}Cf, a production cross section of 13 $\pm$ 5 μb was calculated for ^{246}Es. This is much lower than the original prediction and accounts for the lower production rate. The other Es isotopes seen in the spectra were predicted to have much lower production rates than ^{246}Es. We now believe that the predicted cross sections in this region are not valid for (p, xn) reactions.

We plan to run an Es excitation function to determine optimal proton energies and cross sections for each isotope. If the cross section is large enough, the delayed fission experiment will be repeated to produce more ^{246}Es than we did with 37 MeV protons. This in turn should lead to more fission events and a determination of the P_{DF}.

Footnotes and References

1. SPIT is a version of the JORPLE code with a proximity potential in the entrance channel. The JORPLE reference is J. Alonso, Gmelin Handbuch der Anorganischen Chemie, 7b, 28 (1974.)
2. H. L. Hall, LBL Report LBL-27878 (1989.)
3. S. A. Kreek, LBL Report LBL-33766 (1993.)